

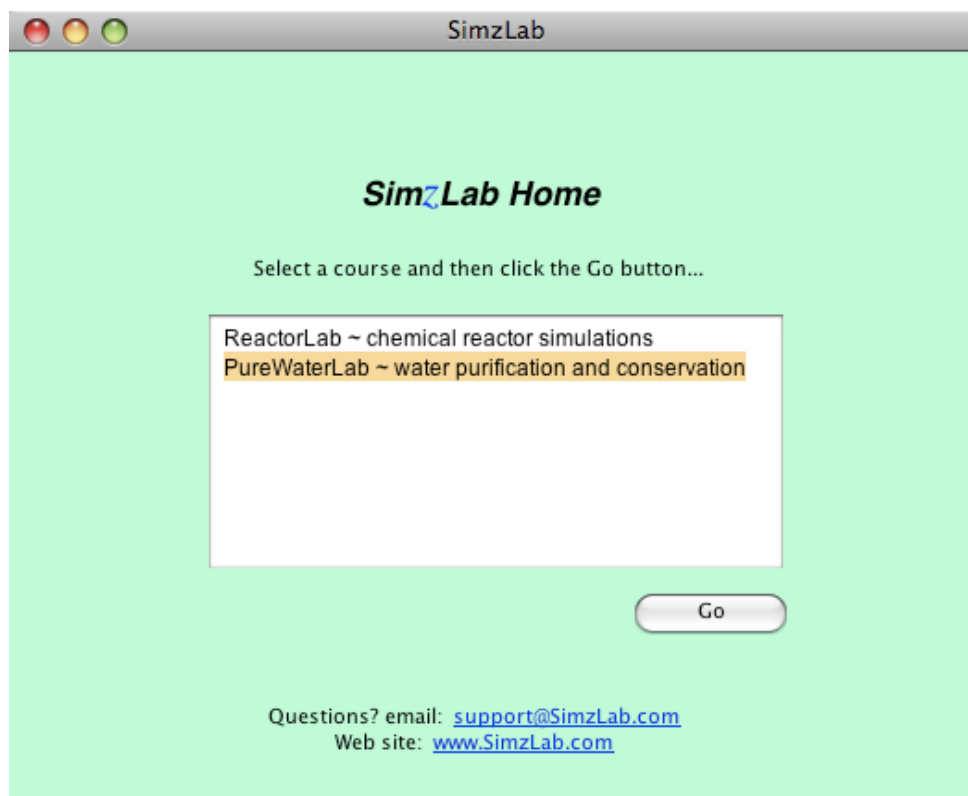
***PureWaterLab - Conservation Education and Research Through Interactive Simulation***

This attachment to the annual report discusses progress and plans for the PureWaterLab project.

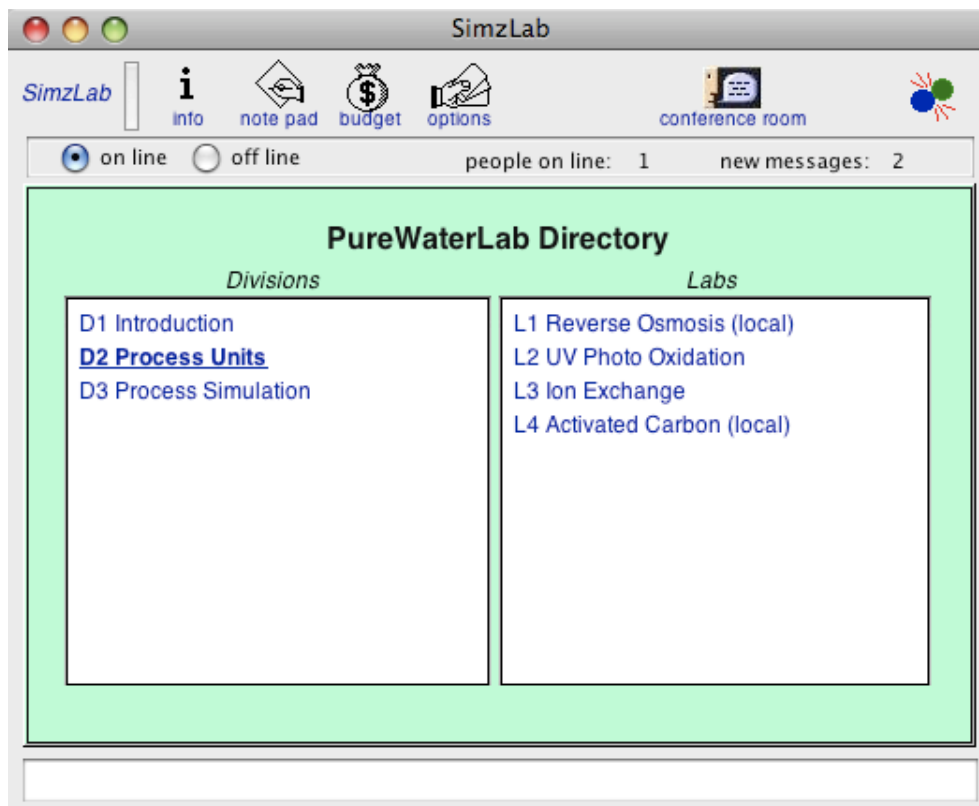
During the past year we continued work on the project in a no-cost extension. Major accomplishments include merging our software codes from two NSF-funded projects into a common code-base, developing additional course modules including those which provide detailed and compute-intensive simulations of physical systems, and continued development of our plant simulator for team collaboration.

In this project and a prior NSF-CCLI project, we developed two sets of interactive simulation modules: Reactor Lab and PureWaterLab. The software codes for these two projects were similar and developing them separately and keeping them both current was a headache. Therefore, this past year we developed a common code-base and a common software application for distribution of both sets of modules. We call this common delivery vehicle, SimzLab. The software can be downloaded at no cost from SimzLab.com.

SimzLab is a desktop application that is integrated with the Internet and associated software on web servers. In the current web jargon, the Lab is a "rich Internet application." When on line, a student can access new modules and communicate in the Conference Room with other students. Updates to software are automatically downloaded and installed. When off line, the student can continue to work on the modules they previously accessed while on line. This is the home screen showing the "courses" currently available. We plan to add new courses in the future.



This is the Directory screen of PureWaterLab. The modules or "Labs" are arranged in "Divisions."



This screen shows the explanatory part of a module on the UV Photo Oxidation method of water purification (screens are not shown at same scale in this document).

**Figure 5. Annulus Reactor with baffles showing water flow**

**Source Radiant Power**

The **source radiant power** ( $\Phi$ ) is the radiant power emitted by any radiant power source in all directions, such as a UV lamp. As stated above, power ratings typically fall between 40-100W for **low-pressure** lamps and 1-5kW for **medium-pressure** lamps (Bolton, 2002). Through a non-absorbing medium, the radiant intensity ( $I$ ) of UV light will not diminish. In this case, for a point source:

$$\Phi = 4\pi I \quad (11)$$

Most UV lamps for UPW application are cylindrical tubes that can be modeled as multiple point sources lined next to each other. This technique is known as **Multiple Point Source Summation (MPSS)** and can be integrated using a technique called **line source integration (LSI)** to find the fluence rate ( $E'$ ) through water as a function of height from the center of the lamp ( $H$ ) and distance from the lamp ( $r$ ) of length ( $L$ ), neglecting absorption and **reflection** (Bolton, 2000):

$$E'(r, H) = \frac{\Phi}{4\pi Lr} \left[ \arctan \left( \frac{L/2 + H}{r} \right) + \arctan \left( \frac{L/2 - H}{r} \right) \right]$$

Source radiant power ~ The total amount of electromagnetic power emitted from a source. The SI unit is watt (W)

This project is a collaboration. The University of California, San Diego (UCSD) part of the team is working on the software programming and the interactive simulations. The University of Arizona (UA) part of the team is working on the main module content, including text, graphics, math equations, and assessment components.

A work process was developed such that the UA group can develop and add new and revised content easily without having to involve the software group at UCSD. The UA group develops content as standard web pages and uploads them to the PureWaterLab server. Whenever a student is using PureWaterLab on-line, the software automatically detects new and updated modules and downloads them for on- or off-line use.

Text can contain links to web sites external to PureWaterLab. These links are opened in the users web browser.

The screenshot displays a web browser window with the address bar showing <http://www.epa.gov/safewater/contaminants/index.html>. The page title is "Drinking Water Contaminants" and it features the U.S. Environmental Protection Agency logo. The page content includes a search bar, navigation links like "Recent Additions" and "Contact Us", and a list of links under the heading "On this page":

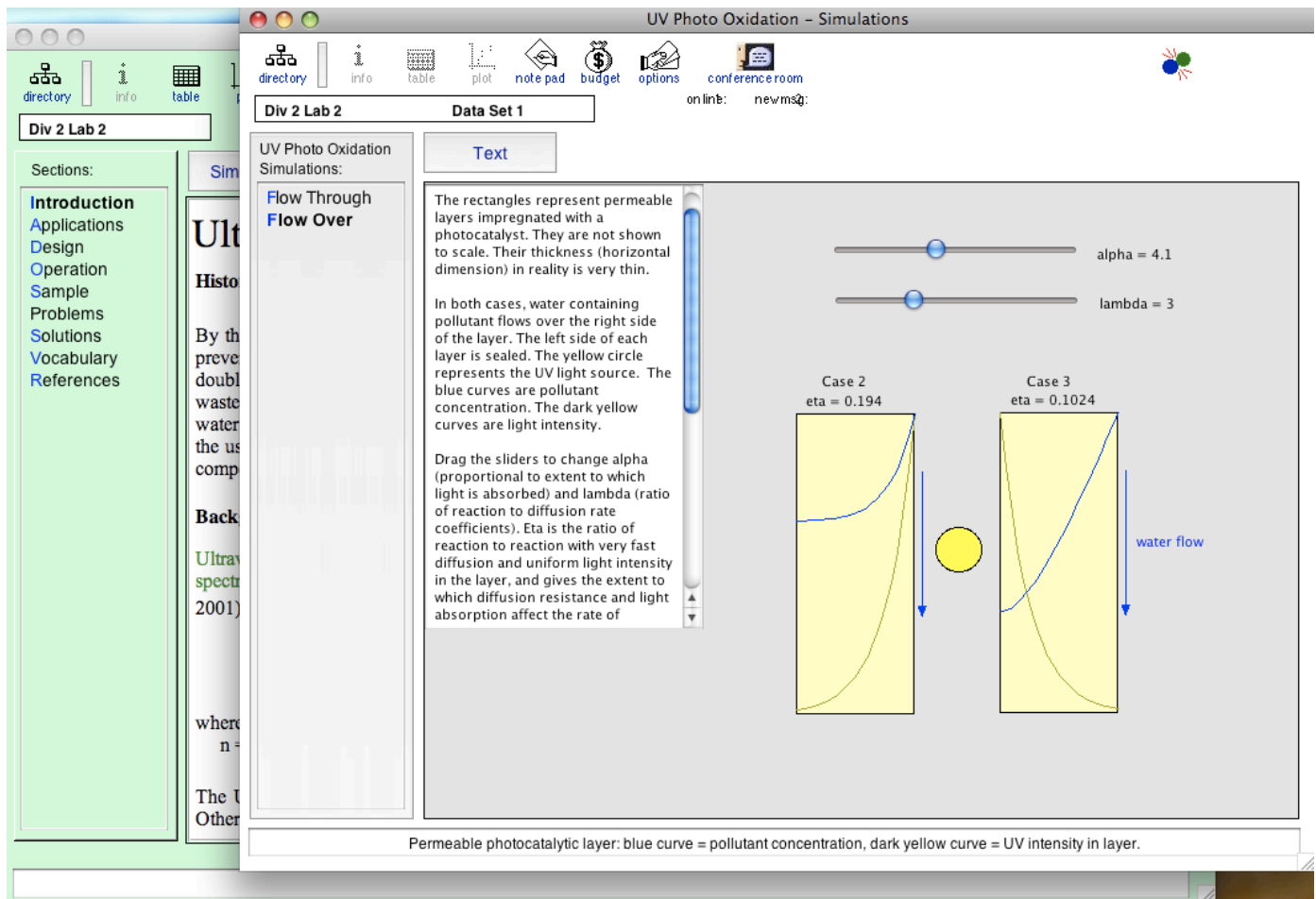
- [National Primary Drinking Water Regulations](#)
  - [List of Drinking Water Contaminants & their MCLs](#)
- [National Secondary Drinking Water Regulations](#)
  - [List of Secondary Drinking Water Regulations](#)
- [Unregulated Contaminants](#)

Below the browser window, the PureWaterLab interface is visible. It includes a toolbar with icons for "directory", "info", "table", "plot", "note pad", "budget", "options", and "conference room". The main content area is titled "References" and lists the following:

- Miller, G.T. Living in the Environment. 13th ed. Brooks/Cole-Thomson, 2004.
- Timberlake, K.C. Basic Chemistry. 1<sup>st</sup> ed. Pearson Benjamin Cummings, 2005.
- Tomcak, M. "Oceanogr. Notes Chapter 1." 12 Nov 1999. Jun 2006  
<http://www.es.flinders.edu.au/~mattom/IntroOc/notes/lecture01.html>.
- U.S. Environmental Protection Agency. "Drinking Water Contaminants." July 2002. EPA. 20 June 2006  
<http://www.epa.gov/safewater/mcl.html>.
- "USGS Estimated Use of Water in the United States in 2000", Fact Sheet 2005—3051, Sep 2005.

On the left side of the PureWaterLab interface, there is a sidebar with "Sections:" and a list of links: "Objectives", "Water Use", "Water Purity", "Ultrapure Water", "Dimensional", "Analysis", "Quizzes", and "References".

The advantage of using these web pages in PureWaterLab, as compared with a standard web browser, is that many other features are additional available in PureWaterLab, such as the interactive simulations. A simulation in the UV Photo Oxidation module is shown below.



Several ways were developed to help students search text and understand vocabulary. A result of a search for a word is shown here.

One special feature provided by the software is automatic scanning of text for words listed in the vocabulary section. Other than preparing the vocabulary section, the content authors do not have to do anything else. The software highlights vocabulary words automatically, and the definition is shown at the bottom of the window when the student passes the cursor over a highlighted word, as shown below.

UV Photo Oxidation

directory info table plot note pad budget options conference room on line: newmsg:

Div 2 Lab 2

Sections:

- Introduction
- Applications**
- Design
- Operation
- Sample
- Problems
- Solutions
- Vocabulary
- References

Simulations

## Applications

There are several functions of UV radiation in UPW disinfection systems. Wavelengths 254 nm and 185 nm are primarily responsible for different treatments, as summarized by DeGenova (2001):

**Table 2. UV Treatment Applications**

| Primary Wavelength (nm) | Function               |
|-------------------------|------------------------|
| 254                     | Bacterial Disinfection |
| 254                     | Ozone Decomposition    |
| 185                     | TOC Oxidation          |

**Bacterial Disinfection**

Every known living organism contains genetic material (DNA and/or RNA). DNA will absorb energy when exposed to UV-C range UV, as shown on Figure 3. This causes photochemical alterations to nucleic acids and damages the cell's ability to reproduce. This mode of inactivation follows first-order disinfection kinetics presented by the AWWA (1990) from Chick and Watson;

$$r = -kN$$

(2)

where:  
 $r$  = rate of inactivation [(organisms killed)/volume/time]  
 $N$  = concentration of viable organisms

Inactivation ~ The sufficient cellular death of microorganisms to prevent reproduction

Another new feature being added are quizzes to assess student learning. Several different types of questions are available, and the software automatically scores the answers and provides feedback, as shown here.

Overview

directory info table plot note pad budget options conference room on line: newmsg:

Div 1 Lab 1

Sections:

- Objectives
- Water Use
- Water Purity
- Ultrapure Water
- Dimensional
- Analysis
- Quizzes**
- References

Simulations

## Quizzes

Links on this page open quizzes.

[Practice Problems](#)

Question:

If it takes 2,000 gallons of Ultrapure Water (UPW) to clean one wafer, how many can you clean with 32,000 gallons?

Enter your answer here (number only, no commas, no units):

16

Check Your Answer attempts Show Correct Answer

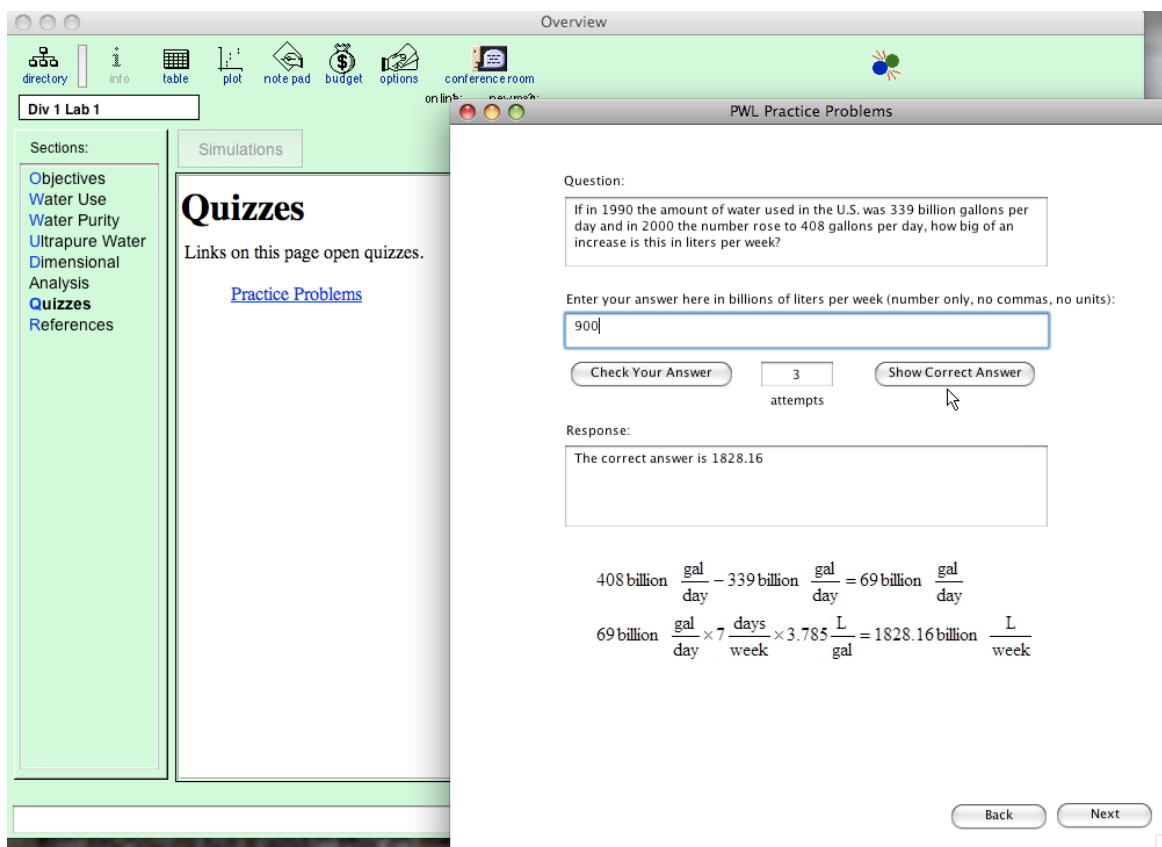
Response:

That's correct!

32,000 gallons ÷ 2,000 gallons = 16 wafers

Back Next

If a student enters incorrect answers several times, they are allowed to view the correct answer.



One of the developments in 2008-2009 was development of interactive simulations which can provide very detailed, compute-intensive simulations of physical processes. Whereas the cross-platform software language that is used for most of the project has sufficient speed to handle most simulations, compiled executables need to be used for more demanding simulations.

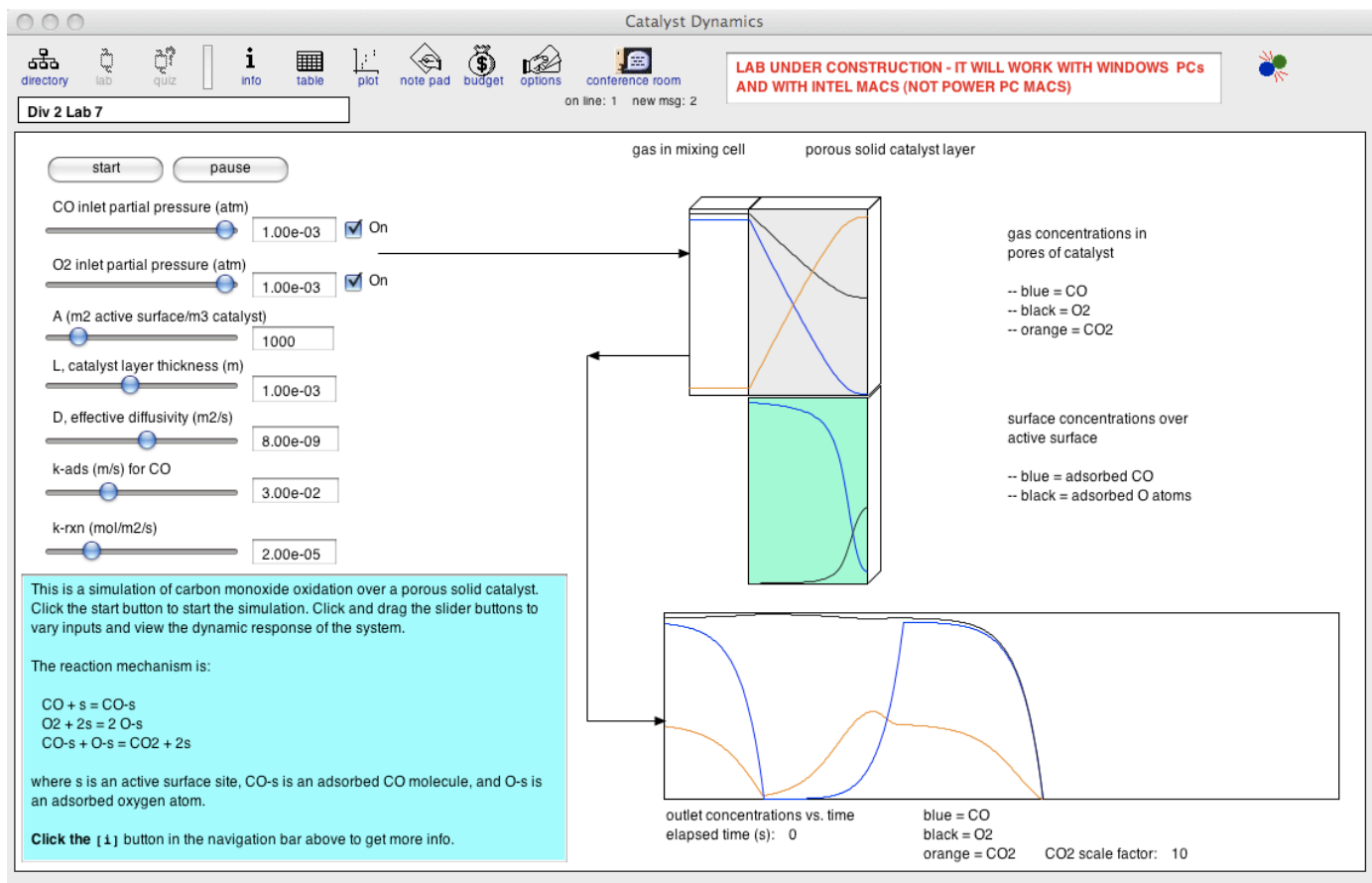
One of our visions is to provide undergraduate students with research-grade simulations where appropriate. Our development this year in this area was to couple simulations in C++ compiled executable files to the Graphical User Interface or GUI and also to deliver those compiled files along with the other module components.

The figure on the next page shows a dynamic simulation in Reactor Lab of the CO oxidation reaction in a porous solid catalyst. When running, the concentration profiles in the gas mixing cell, the pores and surface of the catalyst layer, and the outlet gas concentrations continuously update. The student can change parameters and the gas inputs by moving the sliders.

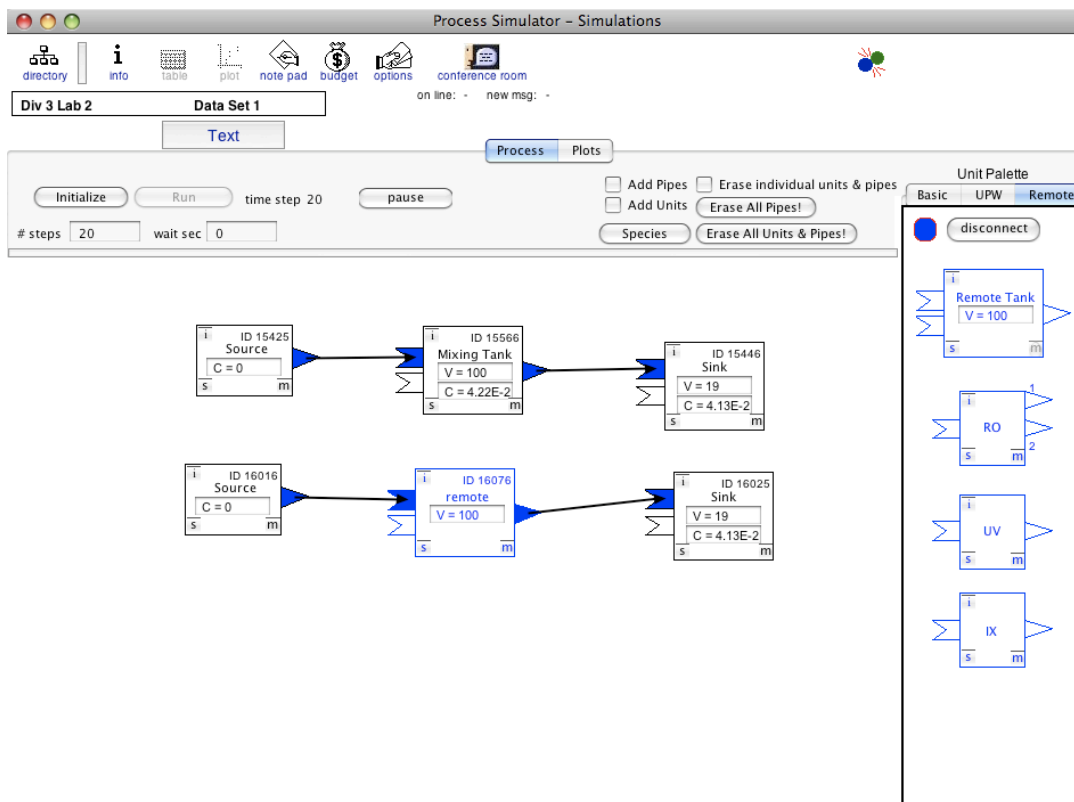
At each time step in the GUI, the module sends the current values of the inputs to the compiled executable file which then integrates the system equations for many internal time steps, returns the output to the GUI, and then the GUI updates the plots.

This procedure will be used to develop other detailed simulations.





Progress is continuing to be made on the plant simulator to allow for inter-campus collaboration on simulations. The figure below shows the simulator with two processes in parallel.



Each process consists of a water source, a pipe to a mixing tank, and a pipe to a sink. There is a contaminant component in the water leaving the source, whose concentration "C" is shown.

In the top process, all units are "local" in the sense that they are computed on the client computer on which this copy of PureWaterLab is resident. In the bottom process, the blue unit is a local proxy for the actual unit which resides on a remote computer. When running, the water flowing through the pipes is carried by "messages" which are passed from unit (software object) to unit. Messages sent to a local proxy for a remote unit are sent over the Internet to the remote unit via TCP/IP socket messages. The remote unit updates its state and sends a return message back to its proxy on the original computer.

Messages sent between local units are written in the language of the local client. Messages sent across the Internet are written in cross-platform XML text. Because these messages are written in XML, the different simulators on the different computers which participate in a simulation can be written in any computer language and run on any operating system on any hardware.

The major progress on the simulator during the last year was to speed up the execution of the simulation and to test running collaborative simulations between UCSD and U. Arizona.

Development of the simulator will continue. Our vision is to enable student groups at different universities to collaborate on designing and running plants. During a collaborative simulation, students will be able to communicate via text messages using the technology developed for the Lab's current Conference Room.

Some grant funds remain and we remain committed to development of the project, so we are requesting a no-cost extension for an additional year. Continuation will allow the graduate student at UCSD to finish the PhD degree and will allow undergraduate students at U. Arizona to develop more course modules and test the modules in courses.